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Linear Programming Technique and its' Application in Minimizing Piggery Feed Meals formulation in a Piggery Farm in Ghana

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ABSTRACT

In this paper, we develop an optimal feed mix formulation model for the piggery farm industry utilizing locally and accessible feed ingredients in other to achieve an optimal productivity in piggery farming in Ghana using information from a typical standard farm to form the Linear Programming model for the feed composition created and parameterized by considering both the decision and constraints variables, to determine the optimal solution. Results from the values measured and post optimality shows that the optimal reduction in the pig's ration of 8.89% decrease in the pigs feed formulation related to the farm's existed procedure.

Keywords: Linear, Programming, Application, Model, Decision, Constraints, Variable

INTRODUCTION

Piggery business has a considerable impact on the national economy; it is a well-liked sector for smallholders and makes a significant contribution to GDP and job growth. Over seventy 70 percent of the cost of raising pigs goes toward their feed, so an effective feed formulation process is hereby necessary for a viable piggery sector. However, many piggery farmers use ineffective techniques to address feed formulation issues such as firsthand knowledge, and intuition thereby making their effort unfruitful.

According to [1] approximately the majority of rural people in developing world depend on animals for a living, either partially or entirely. Raising livestock has many advantages such as earnings, meals, animal waste, draft power, transporting services, investments, insurance, and status in society as opined by [2]

According to [3] the rise in pork intake is one of the livestock industry's fastest-growing divisions is the intensive livestock sector, which supports family income as [4] opined that pork output rises from 11,173 metric tons in 1999 to 17,512 metric tons in 2009, with production indexes one rising from 98 to 154.

Many farmers rely on piggery for meat, work opportunities, nutrition security, and investments for storage or trade, and it is an important part of their socioeconomic and cultural identities. It also provides food, work opportunities, and nutrition security, as well as store or trade assets as opined by [5]

According to [6] Ghana piggery farmers have the ability to produce 66.8% of the country's GDP from livestock and crops as stated by minis try of food and agriculture as. Growing pigs and other indigenous livestock species is essential to Ghanaian farming techniques. Systems which may be categorized as free-range, intensive, or semi-intensive farming [7] Opined that lack of better breeders, a compromise between accessibility of land and water constraints brought on by urbanization processes, pollution, and an absence of managerial expertise have all impeded the growth of Ghana's domestic piggery farm business.

For these reasons [8] Suggested that government should create a number of research and development (RD) programs, grants, research institutions, and other initiatives in other to assist the piggery farmers as raising pigs is a crucial part agricultural sector and a significant source of income for many business people seeking alternate routes to successful operations as opined by [9]

LINEAR PROGRAMMING

Here we formulate and adopt the linear programming (LP) method which is one of the most widely used optimization techniques and perhaps the most effective method. The term linear programming was coined by [1] to refer to problems in which both the objective function and constraints are provided.

We consider the following standard form of linear programming

$$\text{Maximize F= } \sum_{j=0}^{n} c_j u_i \tag{1}$$

Subject to

$$\sum_{i=0}^{n} a(i,j)u_j = b_i, i = 1,2 \ldots \ldots . n \tag{2}$$

$$l_j \leq U_j \leq t_j, j = 1,2, \ldots., n \tag{3}$$

Where C_j are the n objective performance coefficient a (i,j) and b_j are parameters in the m linear inequality constraints and l_j and t_j are lower and upper bounds with $l_j \leq t_j$. Both l_j and t_j may be positive or negative.

Linear Programming Model Formulation Models for Pig Feed Mix

Here we apply the above Mathematical models for pigs' meal mix ration using limited and available ingredients in other to minimize the cost of producing a particular diet and meals after satisfying a set of constraints. These restrictions mostly came from [12] restrictions on ingredients and the pigs' nutrient needs. According to [13] the parameters in the models were the cost and nutrient value of each component, whereas the variables in the models were those

two factors. These restrictions mostly came from [12] restrictions on ingredients and the pigs' nutrient needs. According to [13] the parameters in the models were the cost and nutrient value of each component, whereas the variables in the models were those two factors. Here we apply the linear Programming models to optimize pigs feed ration using limited and available ingredients in other to minimize cost of producing a particular diet and meals satisfying a set of constraints.

$$\text{Minimize } P=\sum_{j=0}^{n} c_j u_i \tag{4}$$

Subject to

$$\left.\begin{array}{c} u_1 + u_2 + u_3 + u_4 + u_5 \ldots\ldots\ldots\ldots + u_{10} = b_1 \\ a_{11}u_1 + a_{12}u_2 + a_{13}u_3 + a_{14}u_4 + a_{15}u_5 + \cdots + a_{10}u_{10} \leq b_2 \\ a_{21}u_1 + a_{22}u_2 + a_{22}u_3 + a_{24}u_4 + a_{25}u_5 + \cdots + a_{20}u_{10} \leq b_3 \\ a_{31}u_1 + a_{32}u_2 + a_{32}u_3 + a_{34}u_4 + a_{35}u_5 + \cdots + a_{30}u_{10} \leq b_4 \\ a_{41}u_1 + a_{42}u_2 + a_{42}u_3 + a_{44}u_4 + a_{45}u_5 + \cdots + a_{40}u_{10} \leq b_5 \\ a_{51}u_1 + a_{52}u_2 + a_{52}u_3 + a_{54}u_4 + a_{55}u_5 + \cdots + a_{50}u_{10} \leq b_6 \\ a_{61}u_1 + a_{62}u_2 + a_{62}u_3 + a_{64}u_4 + a_{65}u_5 + \cdots + a_{60}u_{10} \leq b_7 \\ a_{71}u_1 + a_{72}u_2 + a_{72}u_3 + a_{74}u_4 + a_{75}u_5 + \cdots + a_{10}u_{10} \leq b_8 \\ a_{81}u_1 + a_{82}u_2 + a_{82}u_3 + a_{84}u_4 + a_{85}u_5 + \cdots + a_{10}u_{10} \leq b_9 \\ u_j \geq 0, i = 1,2,3,\ldots,n \end{array}\right\} \tag{5}$$

Where P = Cost of the ration, C_j = Ingredient price, j=1,2,3.....m u_i = Ingredient quantity, i=1,2,3.....n a_i = Technical coefficients of nutrient components in feedstuffs, b_i = Constraints of the ration.

Assumptions

The following were the assumption made in formulating the linear programming model:

1. All the projects and constraints are independent on each other.
2. Equal investment opportunities are assumed for the projects in each period.
3. The financial cash flows. Resources and constraints are known with certainty

DATA COLLECTION AND ANALYSIS

Recommended nutrient requirements schedule for both sow and winners' pigs were collected from Ghana Veterinary service limited which includes feedstuffs and nutrients used in ration formulation in piggery farms and mathematically designated as shown in table1 and 2 below: maize (u_1), Rice Bran (u_2), Wheat Flour (u_3), Soya bean Meal (u_4), Meat Meal (u_5), Cotton (u_6), Fish Meal (u_7), Cassava/starch (u_8), Methionine (u_9), Molasses (u_{10}).

Table1: Standard feedstuffs and Nutrient levels ingredients in Pig feed meal

Ingredient	Cost/kg	Protein	Fat	Lysine	Methionine	Phosphorus	Calcium	Fiber	ME
u_1	2.60	8.8	4.0	2.0	0.1	0.34	0.4	0.18	3432
u_2	2.40	48	3.5	6.5	0.2	0.37	3.2	0.59	2557
u_3	2.00	13	0	5.1	0.05	1.20	0.5	0.42	3153

u_4	2.80	60	4.5	1.0	6.5	3.5	4.5	1.8	2950
u_5	7.00	95	0	0	0	0	100	0	0
u_6	2.60	12	0.25	4.75	1.50	1.50	0.2	0.15	1260
u_7	3.00	0	0	0	0	0	0	0	0
u_8	1.40	39.6	0	0	0.15	0.48	62.8	71.9	2350
u_9	0.24	0	0	0	38	0	0	0	0
u_{10}	7.00	60	0	0	0	0	0	10	0

Table 2: Least-cost formulation restrictions on nutrients and feedstuffs for wiener and sow ration

Nutrients		Wiener			Sow	
	Max	Min	Constraints	Max	Min	Constraints
Crude protein (%)	-	23	≤ 23	-	18	≤ 18
ME(Kcal/kg)	3200	2800	≤ 230	3400	3200	≤ 3200
Calcium (%)	15	10	≥ 15	25	10	≤ 10
Phosphorus (%)	-	45	≤ 40	-	35	≤ 35
Fat (%)	50	-	≥ 50	60	-	≥ 60
Crude Fiber%	30	-	≥ 30	50	-	≥ 50
Lysine%	-	10	≤ 11	-	11	≤ 11
Methionine%	-	5	≤ 5	-	5	≤ 5

Formulation and Implementation of Linear Programming Model Implementation

We develop two Linear Programming model for the pig feed meals as follows:

1. Linear Programming model for least cost of wiener ration
2. Linear Programming model for least cost sow ration

We then insert the value of the ingredients obtained from the farmer and that of the Veterinary service in tables 1 and 2 into the model in equation (4) as shown in table 3a, b and 4 below:

$$Min(P) = 2.6_{u1} + 2.4_{u2} + 2u_3 + 2.8u_4 + 7u_5 + 2.6u_6 + 3u_7 + 1.4u_8 + 0.24u_9 + 7u_{10}$$

Subject to:

$$\left.\begin{array}{c} u_1 + u_2 + u_3 + u_4 + u_5 + u_6 + u_7 + u_8 + u_9 + u_{10} \leq 1000 \\ 8.8u_1 + 48u_2 + 13u_3 + 60u_4 + 95u_5 + 12u_6 + 39.6u_8 \leq 23 \\ 4u_1 + 3.5u_2 + 4.5u_3 + 0.25u_6 \leq 50 \\ 2u_1 + 6.5u_2 + 5.1u_3 + 1u_4 + 4.75u_6 \leq 50 \\ 0.1u_1 + 0.2u_2 + 0.05u_3 + 6.5u_4 + 1.5u_6 + 0.15u_8 + 38u_9 \leq 15 \\ 0.34u_1 + 0.37u_2 + 1.2u_3 + 3.5u_4 + 1.5u_6 + 0.48u_{10} \leq 45 \\ 0.40u_1 + 3.2u_2 + 0.5u_3 + 4.5u_4 + 100u_5 + 0.2u_6 + 62.8u_8 \leq 11 \\ 0.18u_1 + 0.59u_2 + 0.42u_3 + 1.8u_4 + 0.15u_6 + 71.9u_8 + 100u_{10} \leq 5 \\ 3432u_1 + 2557u_2 + 3153u_3 + 2950u_4 + 1260u_6 + 2350u_8 \leq 2800 \\ u_1, u_2, u_3, u_4, u_5, u_6, u_7, u_8, u_9, u_{10} \geq 0 \end{array}\right\}$$

Table 3a: Feasible and initial Tableau for the least cost wiener

	u_1	u_2	u_3	u_4	u_5	u_6	u_7	u_8	u_9	u_{10}	S_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	RHS
Z	-2.6	-2.4	-2	-3	-7	-3	-3	-1.4	-0.2	-7	1	0	0	0	0	0	0	0	0	0
S_1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	1000
s_2	8.8	48	13	60	95	12	0	40	0	0	0	0	1	0	0	0	0	0	0	23
s_3	4	3.5	4.5	0	0	0.	0	0	0	0	0	0	0	1	0	0	0	0	0	50
s_4	2	6.5	5.1	1	0	4.8	0	0	0	0	0	0	0	0	1	0	0	0	0	50
s_5	0.1	0.2	0.1	6.5	2	0	0	0.2	38	0	0	0	0	0	0	1	0	0	0	15
s_6	0.3	0.37	1.2	3.5	0	2	0	0	0	.5	0	0	0	0	0	0	1	0	0	45
s_7	0.4	3.2	0.5	4.5	100	.2	0	63	0	0	0	0	0	0	0	0	0	1	0	11
s_8	0.2	0.59	0.4	1.8	0	.2	0	72	100	0	0	0	0	0	0	0	0	0	1	5
s_9	3432	2557	3153	2950	0	2350	0	2350	0	0	0	0	0	0	0	0	0	0	0	2800

Implementation of Linear Programming Model for the Least Cost Sow Ration

Here, we insert the value of the ingredients obtained from the farmer and that of the Veterinary service as shown in tables 1 and 2 into the model as follows:

$$Min(Z) = 2.6u_1 + 2.4u_2 + 2u_3 + 2.8u_4 + 7u_5 + 2.6u_6 + 3u_7 + 1.4u_8 + 0.24u_9 + 7u_{10}$$

Subject to:

$$\left.\begin{array}{c} u_1 + u_2 + u_3 + u_4 + u_5 + u_6 + u_7 + u_8 \leq 1000 \\ 8.8u_1 + 48u_2 + 13u_3 + 60u_4 + 95u_5 + 12u_6 + 39.6u_8 \leq 21 \\ 4u_1 + 3.5u_2 + 4.5u_3 + 0.25u_6 \leq 60 \\ 2u_1 + 6.5u_2 + 5.1u_3 + 1u_4 + 4.75u_6 \leq 50 \\ 0.1u_1 + 0.2u_2 + 0.05u_3 + 6.5u_4 + 1.5u_6 + 0.15u_8 + 38u_9 \leq 15 \\ 0.34u_1 + 0.37u_2 + 1.2u_3 + 3.5u_4 + 1.5u_6 + 0.48u_{10} \leq 45 \\ 0.40u_1 + 3.2u_2 + 0.5u_3 + 4.5u_4 + 100u_5 + 0.2u_6 + 62.8u_8 \leq 11 \\ 0.18u_1 + 0.59u_2 + 0.42u_3 + 1.8u_4 + 0.15u_6 + 71.9u_8 + 100u_{10} \leq 5 \\ 3432u_1 + 2557u_2 + 3153u_3 + 2950u_4 + 1260u_6 + 2350u_8 \leq 3200 \\ u_1, u_2, u_3, u_4, u_5, u_6, u_7, u_8, u_9, u_{10} \geq 0 \end{array}\right\}$$

Table 3b: Feasible and initial Tableau for the least cost of Sow pigs

	u_1	u_2	u_3	u_4	u_5	u_6	u_7	u_8	u_9	u_{10}	S_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	RHS
Z	-2.6	-2.4	-2	-2.8	-7	-3	-3	-1.4	-0.2	-7	0	0	0	0	0	0	0	0	0	0
S_1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	1000
s_2	8.8	48	13	60	95	12	0	40	0	0	0	1	0	0	0	0	0	0	0	21
s_3	4	3.5	4.5	0	0	0.3	0	0	0	0	0	0	1	0	0	0	0	0	0	60
s_4	2	6.5	5.1	1	0	5	0	0	0	0	0	0	0	1	0	0	0	0	0	50
s_5	0.1	0.2	0.1	7	1.5	0	0	0.2	38	0	0	0	0	0	1	0	0	0	0	15
s_6	0.4	0.4	1.2	4	0	2	0	0	0	.5	0	0	0	0	0	1	0	0	0	45
s_7	0.4	3.2	0.5	6	100	.2	0	63	0	0	0	0	0	0	0	0	1	0	0	11
s_8	0.2	0.6	0.4	1.8	0	0.2	0	72	100	0	0	0	0	0	0	0	0	1	0	5
s_9	3432	2557	3153	2950	0	2350	0	2350	0	0	0	0	0	0	0	0	0	1	0	3200

MATLAB PACKAGE SOLUTION OF LEAST COST FOR PIGS FEED MEAL RATION

Table 4: LP Model for Least Cost for pigs rationing solution using MATLAB Package

Decision	Unit cost	Solution variable		Total cost		Reduced cost	
		Winners	Sow	Winner	Sow	Winners	Sow
Maize(u_1)	2.6	510	656	1326	1706.64	-26	-68.64
Rice Bran (u_2)	2.4	200	80.9	480	194.16	00	165.94
Wheat (u_3)	2.0	00	00	00	00	146	60
Soya bean(u_{l4})	2.8	00	00	00	00	144	70
Meat meal(u_5)	7.0	1.2	00	8.4	00	-1.4	17.5
Cotton(u_6)	2.6	100	119	260	308.62	-78	--9.62
Fish meal(u_7)	3.0	1	1	3	3	00	00
Cassava(u_8)	1.4	00	00	00	00	35	5.6
Methionine(u_9)	0.24	86	40.7	20.4	9.77	-8.64	-.17
Molasses(u_{10})	7.0	1.8	3.4	12.6	23.8	-9.06	-1.4
Total Optimal cost						**205.90**	**239.11**

Discussion

From the MATLAB software result, the amounts of wheat bran, soya bean, beef meal, and cassava are reduced zero (0 kg) this is due to the presence of nutrients value other ingredients. To compensate for the lack of nutrients provided by the wheat bran, soya bean, and cassava, more maize, cotton, methionine, and molasses should be added to the diet. The amount of nutrients in methionine was decreased, while the nutrient in the fishmeal was increased. In this case the model minimized the cost of the feeding to GHc205.90.per feed formulation.

Likewise, the quantity of wheat bran, soya bean, beef meal, and cassava were reduced to zero kilograms (kg) because the other components (a constraint) already contain nearly all of the nutritional value they provide. To make up for the lack of nutritional value that would have been provided by the wheat bran, soya bean, beef meal, and cassava, more maize, cotton, methionine, and molasses were added. To balance the feed's nutritional content, the amount of rice bran was decreased, and fishmeal was increased. The feed cost is decreased by this model by nearly GH 239.11

Determination of the Cost-Effectiveness in the Pigs Feed Meal Ration

Here we determine the most cost-effective in the current feed meal procedures for the pig's ration using mathematical models as given in the Tables 5 below:

Table 5: shows cost effectiveness of the Pigs feed meal ration

Ingredients	Cost	Wiener						Sow	
		Current		Proposed		Current		Proposed	
		Value	Cost	Value	Cost	Value	Cost	Value	Cost
($u1$)	2.6	500	1300	510	1326	630	1638	510	1581
($u2$)	2.4	200	480	200	480	150	360	200	580
($u3$)	2	73	146	0	0	30	60	0	0

($u4$)	2.8	80	144	0	0	25	70	0	0
($u5$)	7	1	7	1.2	8.4	2.5	17.5	1.2	9
($u6$)	2.6	70	182	100	260	115	299	100	310
($u7$)	3	1	3	1	3	1	3	1	3.5
($u8$)	1.4	25	35	0	0	4	5.6	0	0
($u9$)	0.24	50	12	86	20.64	40	9.6	86	63.64
($u10$)	7	1	7	1.8	12.06	3.2	22.4	1.8	13.5
		1001	**2316**	900	**2110.1**	1000.7	**2485.1**	900	**2560.64**

Based on the formulated Linear Programming model, the cost of new formulated Wiener feeds is GH¢ 2110.10 against the existing cost of feed formulation which was GH¢2316.00 with a difference of GH¢205.90 per feed meal formulation. This result yields an impressive saving of 8.89% per feeds formulation. While the Sow feed formulation costs GH¢2245.99 against GH¢2485.10 with a difference of GH¢239.11 which represents a considerable decrease of approximately 9.62%. Per feed formulation.

Sensitivity Analysis on the Pigs Ration

Here we examine the effects of changes or variations in selected key parameters on the model. Here the cost of the various ingredients/kg was increased and decreased by 5% The sensitivity analysis demonstrate that the proposed pigs ration is robust to changes in the unit costs of the ingredients, and strictly adapt to cost fluctuations while maintaining the same total cost and nutritional quality for the Pigs rations. The effects of variations of the cost of the ingredients use in the feed mix was analyzed as presented in Table 6.

Table 6: shows the effect of variation in the Pig feed ration

Increased Cost by 5%						**Decreased Cost by 5%**				
		Current		**Proposed**		**Ingredient. Cost**	**Current**		**Proposed**	
Ingre dient	Cost	Value	Cost	Value	Cost		Value	cost	Value	Cost
(u_1)	3.10	500	1550	510	1581	2.10	630	1323.00	656.4	1378
(u_2)	2.90	200	580	200	580	1.90	150	285.00	80.9	154
(u_3)	2.50	73	182	0	0.00	1.50	30	45.00	0	0.00
(u_4)	3.30	80	264	0	0.00	2.30	25	57.50	0	0.00
(u_5)	7.50	1	7.50	1.2	9.00	6.50	2.5	16.25	0	0.00
(u_6)	3.10	70	217	100	310	2.10	115	241.50	119	249
(u_7)	3.50	1	3.50	1	3.50	2.50	1	2.50	1	2.50
(u_8)	1.90	25	47.50	0	0.00	0.90	4	3.60	0	0.00
(u_9)	0.74	50	37	86	63.64	-0.26	40	-10.40	40.7	-10.58
(u_{10})	7.50	1	7.50	1.8	13.50	6.50	3.2	20.80	3.4	22.10
Opt. value		**1001**	2897	**900**	2561	2.10	1000.7	1984.75	900.1	1795.44

CONCLUSION

This paper deal with optimizing feed mix formulation for the piggery farm industry utilizing locally and accessible feed ingredients to achieve an optimal productivity in piggery farming in

Ghana using information from a typical standard farm to form the Linear Programming model for the feed composition created and parameterized by considering both the decision and constraints variables, to determine the optimal solution. Results from the values measured and post optimality shows that the optimal reduction in price of the pigs' ration of 8.89% and 9.62% decrease in wiener and sow's ratio respectfully Aside, the new price per ton of the ration cost GH¢2110.10 against the existing cost of feed formulation which was GH¢2316.00 with a difference of GH¢205.90 per feed meal formulation. This result yields an impressive saving of 8.89% per feeds formulation. While the Sow feed formulation costs GH¢2245.99 against GH¢2485.10 with a difference of GH¢239.11 which represents a considerable decrease of approximately 9.62%. Per feed formulation.

It was therefore recommended that since the viability of every piggery farm depends on cost management application of linear programming model approach in feed formulation and implementation will increase production and minimize cost of production in any industry.

Conflicts of Interest

The authors hereby declare that there is no conflict of interests in the preparation and submission of this manuscript

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